Background Information

The present invention relates to a method and a device for providing control variables for guiding a motor vehicle.

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Vehicle guidance systems are known that support the driver during longitudinal guidance of the vehicle (acceleration and deceleration) and/or during transverse guidance (tracking, steering). The functions of such guidance systems range from
10 simple speed regulation to a desired speed selectable by the driver via adaptive cruise control (ACC) in which the distances to preceding vehicles are also taken into consideration, to completely autonomous vehicle guidance. Further examples of functions of such a vehicle guidance
15 system include the automatic generation of collision warnings or the automatic introduction of emergency braking or evasive maneuvers to avoid or minimize the effects of collisions. The traffic situation is determined using sensors attached to the vehicle, the signals of which are supplied as input quantities
20 to a control unit. The input quantities relate to the motion values of the guided vehicle itself, e.g. its driving speed, acceleration, yaw velocity, and the like, as well as to information regarding the traffic environment, in particular location data for preceding vehicles and other obstacles as
25 well as any applicable information regarding the road course, the road condition, and the like. One or more distance sensors are typically provided for acquiring location data, e.g. a radar sensor for measuring distances and relative speeds of radar targets, in the case of a radar sensor having angular
30 resolution also for measuring the azimuth angle of the radar targets, or lidar sensors, or camera systems, in particular stereo camera systems having electronic image processing. The control unit uses the input quantities supplied by these

sensors to calculate control variables that act on the vehicle via control elements of the drive system and in some instances also of the braking system. An example of an ACC system of this type is described in SAE paper no. 96 10 10 "Adaptive

5   Cruise Control System, Aspects and Development Trends", Winner et al., 1996.

The calculation of the control variables by the control unit depends on a plurality of parameters of which several may be

10   changed dynamically even during the control operation as a function of the traffic situation.

For example, during radar-supported distance control, a plurality of objects are typically located at the same time by

15   the radar system. An object list is then created in which the individual objects are represented by their distance, relative speed, and angle data. During the periodically repeated radar measurements, a tracking procedure is used to identify the objects detected in the current measurement via the objects

20   detected in previous measurements, and the movements of the individual objects are tracked. Since according to distance control a vehicle directly ahead in the same lane is to be followed at a suitable safety distance, a parameter is required that specifies which of the plurality of objects is

25   to be selected as the target object for the distance control. This parameter must be adjusted to the particular traffic situation on the basis of suitable criteria.

In practice, the input signals transmitted from the sensors to

30   the control unit are more or less noise-infested and must therefore be processed using a suitable filter. Each of these filter procedures is influenced by one or more parameters that determine the temporal resolution of the filter, e.g. integration times, decay rates, or the selection of frequency

ranges in the frequency spectrum of the signal. The filters must each be parameterized such that sufficient noise and interfering signal suppression is achieved and also that input quantity changes are transmitted with sufficient speed to allow for timely reaction of the guidance system.

Predictive controllers that extrapolate the movements of the own vehicle and those of the located objects for the future, thereby predicting the traffic situation for a future point in time are often used in the control unit. The control variables are then calculated such that an optimum adjustment to the predicted traffic situation is achieved within a certain optimization time interval. Longer prediction time periods and optimization time intervals lead to "predictive" performance of the guidance system and as such to significant driving comfort but have the disadvantage that the probability of false forecasts increases and suddenly occurring changes may not be reacted to appropriately in some instances. Therefore, these parameters are also to be suitably determined.

Furthermore, it must be decided when predicting the future development of an input quantity, e.g. the distance from an object, whether linear extrapolation is to be performed under the assumption that the relative speed remains constant, or quadratic extrapolation under the assumption of constant acceleration, or an extrapolation of an even higher order. In some instances, in the case of sudden state changes, e.g. during an abrupt braking maneuver of the preceding vehicle, plausible assumptions must also be made in the prediction as to how long this state will last.

In general, the determination of the parameters that determine the behavior of the different control functions of the control unit require an evaluation of the traffic situation. To date, either the measured or derived kinetic state quantities of the

own vehicle and the detected objects, e.g. the speed of the own vehicle, the distance and the relative speed of the preceding vehicle, etc., or simple quantities derived from these state quantities, e.g. the time to collision (TTC), i.e.

5   the calculated time to impact, have been used as the situation-specific quantities for this evaluation.

Advantages of the Invention

10 The method of the present invention having the features specified in Claim 1 and the device having the features specified in the first device claim have the advantage that the different parameters are able to be adapted more efficiently to the particular traffic situation.

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In the method of the present invention, a single evaluation quantity that characterizes the traffic situation and is used as the basis for determining a plurality of parameters is formed from a set of at least two input quantities in order to

20 evaluate the traffic situation. In terms of mathematics, the single evaluation quantity is a scalar function on the vector space defined by the plurality of input quantities. For example, this evaluation quantity may be viewed as a measure of the situation's level of danger. If the evaluation quantity

25 has a high value, the parameters should be adjusted accordingly in the control unit so that the situation is able to be reacted to with a shorter response time. Once this evaluation quantity has been calculated, it is available for determining a plurality of parameters at the same time so that

30 a complex system of evaluation criteria does not need to be checked each time for the determination of the individual parameters. In this manner, minimal calculational effort is required to adjust system performance quickly and efficiently to the traffic situation, particularly in critical situations.

Advantageous embodiments and further refinements of the present invention are provided in the dependent claims.

5   The dependence of the evaluation quantity on the input quantities is preferably provided by an at least two-dimensional characteristic map that is able to be stored digitally in the control unit. The number of dimensions of the characteristic map corresponds with the number of input
10   quantities in the associated set. These input quantities may be used to address the characteristic map memory directly so that the evaluation quantity is able to be determined in the shortest time. Since all or at least several parameters are dependent on the same evaluation quantity, characteristic map
15   storage requires only a reasonable amount of memory space.

It is advantageous for the evaluation quantity to be used for target object selection. Every located object is then allocated to a set of input quantities that includes in
20   particular the distance and the relative speed of the object and is used to form a characteristic evaluation quantity for this object. In the case of a higher-dimensional characteristic map, the set of input quantities may also include for example the relative acceleration of the object,
25   the azimuth angle of the object, the speed of the own vehicle, and the like. The evaluation quantity is then preferably a measure of the relevance of the object so that the target object may be selected in that the object for which the evaluation quantity is greatest is selected. The maximum
30   evaluation quantity then also forms the basis for determining the remaining parameters, such as filter parameters, optimization time intervals, and the like.

The evaluation quantity may be a purely fictitious quantity or may alternatively have a specific physical significance. For example, when approaching a preceding vehicle, the evaluation quantity may be defined by the constant (negative)
5   acceleration that would be necessary to adjust the own vehicle speed to that of the preceding vehicle, i.e., to reduce the relative speed of the target object to zero, without the distance to the target object decreasing to less than a critical minimum distance. This minimum distance may then be
10 dependent on further input quantities, e.g. the own vehicle speed and the time gap selected by the driver (object distance divided by relative speed) with which the target object is followed.

15 If the actual distance to the target object is already less than the critical distance, the evaluation quantity may be defined as the constant acceleration that is needed to increase the object distance within a certain time interval, which may then be dependent on other input quantities, to the
20 critical distance. In total, the evaluation quantity is then defined differently for different regions of the characteristic map, and the two definitions are adapted to one another such that the evaluation quantity is always at the region limit of the characteristic map. The evaluation
25 quantity decreases preferably monotonically in the "object distance" dimension as well as in the "relative speed" distance. Therefore, it increases as the object comes closer and as the approach speed (negative relative speed) increases.

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Drawing

An exemplary embodiment of the present invention is shown in the drawing and explained more closely in the following description.

5 The figures show:

Figure 1 a block diagram of a device for providing control variable for vehicle guidance; and

10 Figure 2 an example of an evaluation quantity defined by a two-dimensional characteristic map.

A control unit 10, which is installed in a motor vehicle and is used to provide control variables for vehicle guidance, is
15 shown in Figure 1. Control unit 10 has an input circuit 12, which receives input quantities from different vehicle sensors, in particular from a speed sensor 14, which measures vehicle speed V of the vehicle, and from a locating device 16, e.g., a radar sensor, which provides location data for
20 preceding vehicles and other potential obstacles. Additional sensors 18, 20, which provide further input quantities el – ek, are only shown as a summary in Figure 1. Alternatively, the functions of sensors 14, 18, 20 may also be assumed by other system components of the vehicle that are capable of
25 providing input quantities. Therefore, for example, speed V, the yaw acceleration of the vehicle, or an input quantity that provides friction coefficients μ of the road may also be provided by an electronic stability system (EPS) of the vehicle.
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In the example shown, input circuit 12 forms a set of three input quantities, namely object distance di, relative speed vri of the object, and azimuth angle φi of the object, for every located object i from the signals of locating device 16.

A filter circuit 22, in which every input quantity is prepared
with the help of a suitable filter, is downstream from input
circuit 12. The function of every filter in filter circuit 22

5   depends on one or more filter parameters. For example, it is
conceivable for an input quantity to be determined in filter
circuit 22 over a specific integration time interval in order
to suppress noise and interference signals. The length of the
integration time interval would then be such a filter

10 parameter. It is also conceivable for a floating mean value to
be formed from an input quantity in that a weighted sum is
formed from the values of this input quantity measured in a
plurality of previous measuring cycles, the weighting factors
reducing exponentially with a certain time constant. This time

15 constant would also be an example of a filter parameter.

In the example shown, the filtered input quantities are
supplied to a prediction unit 24, which predicts the future
temporal development of the input quantities on the basis of

20 the input quantities and the temporal derivations of the same
and determines which value the associated input quantity will
have at a certain time in the future, i.e., after a certain
prediction time period has elapsed. These prediction time
periods may differ in duration for the individual input

25 quantities and are determined as a function of the situation
dynamics and under consideration of the reaction time of the
vehicle guidance system.

Input quantities d_i, vr_i und φ_i recorded, filtered, and

30 predicted for each individual object i are supplied to a
selection module 26, which selects a single object as the
target object from the plurality of objects. As a rule, the
selected target object is the directly preceding vehicle in
the own lane. During target object selection, the probability

that the object is in the own lane is first calculated for
every individual object on the basis of the azimuth angle and
the distance. If this probability is above a certain threshold
value, the object is allocated to the own lane. If a plurality

5 of objects were allocated to the own lane, the object having
smallest object distance di is typically selected as the
target object.

Location data d, vr, and φ of the selected target object is

10 supplied together with the remaining input quantities to a
controller 28, which calculates a control variable a_m for
control element 30 of the vehicle drive system or a control
variable a_b for control element 32 of the vehicle brake
system, from these input quantities using known control

15 algorithms.

In the present example, downstream in controller 28 is a
limiting unit 34, which limits control variables a_m and a_b
and/or their change rates such that abrupt acceleration or

20 braking operations are prevented thereby achieving high
driving comfort. The control variables limited in this manner
are then output via an output circuit 36 to control elements
30, 32.

25 The functions of filter unit 22, prediction unit 24, selection
module 26, controller 28, and limiting unit 34, which are
shown in Figure 1 as separate blocks for the sake of clarity,
may be performed in practice by one or more microprocessors.

30 Filtered input quantities V, el – ek, di, vri, φi as well as
any derived quantities, e.g. temporal derivations, are
supplied to an evaluation module 38, which forms a single
evaluation quantity gi, which provides a measure of how
critical the particular traffic situation is with regard to

the respective object, from these quantities for every located object. Object-specific evaluation quantities gi are supplied to selection module 26 and are used there as there as criteria for target object selection: The object for which evaluation

5   quantity gi is greatest is selected as the target object. This maximum evaluation quantity g is then transmitted from selection module 26 to filter unit 22, prediction unit 24, controller 28, and limiting unit 34 and determines there the selection of the filter parameters, the prediction time

10   periods, as well as additional parameters of the control algorithms executed in controller 28 and the limiting function of limiting unit 34. These parameters are optimized in this manner to the particular traffic situation.

15   If a high value of maximum evaluation quantity g indicates a critical situation, the filter parameters in filter unit 22 and the parameters in controller 28 are generally changed in terms of a shorter response time, and the prediction time periods in prediction unit 24 may be shortened. The limiting

20   functions in limiting unit 34 may be changed such that greater accelerations or decelerations as well as faster changes in acceleration and deceleration values are allowed in critical situations.

25   A basic component of evaluation module 38 is a multi-dimensional characteristic map, e.g. in the form of a digital characteristic map memory, which is addressed by the microprocessor or one of the microprocessors using digital data representing the input quantities. The number of

30   dimensions of the characteristic map corresponds with the number of considered input quantities, including the quantities derived therefrom in some instances. However, only one dimension is provided for object distances di of the different objects and accordingly also for the relative speeds

and the azimuth angle of the objects. Evaluation quantities gi are formed consecutively in that the characteristic map memory is addressed in each case with the data for the respective object.

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Figure 2 shows a simplified example of a two-dimensional section of a characteristic map 40 having dimensions d (object distance) and vr (relative speed of the object). Curves 42 drawn in in the characteristic map represent "isolines" for

10   which evaluation quantity g (object subscript i is dispensed with in this instance) has a constant value in each case. As a result, isolines 42 divide the characteristic map into zones having different values of g (g = 1, g = 2, ...).

15   In the present example, isolines 42 each have a parabola-shaped section corresponding with the function:

$$d = d0 + vr^2/(2*g) \qquad\qquad (1)$$

20   This is based on the following physical interpretation: It is assumed that the own vehicle is approaching a preceding vehicle at a distance d with relative speed vr (vr is negative). Evaluation quantity g then represents the constant deceleration (negative acceleration) of the vehicle that would

25   be necessary for the own vehicle to approach the object at a certain critical distance d0 and be braked to the absolute speed of the object so that vr = 0 is true. The absolute speed of the object is used as a constant in this process.

30   The above interpretation is of course only practical when actual object distance d is greater than d0. In limit case d = d0, the vehicle deceleration and as such evaluation quantity g would have to assume infinitely high values which is physically impossible. Therefore, following equation (2) is

used as the determination equation for isolines 42 instead of
above equation (1) in the case of short object distances:

$$d = d0 - T*vr - g*T^2/2 \qquad (2)$$

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The physical interpretation of this equation (2) is that
evaluation quantity g corresponds with the constant vehicle
deceleration that is necessary to achieve critical distance d0
within a certain time period T. The definition is also usable
10   under the condition d < d0. Equation (2) is the equation of a
straight line and therefore corresponds with a straight
section of respective isoline 42. The parabola-shaped section
and the straight section are continuously connected to one
another for every value of g so that a continuous
15   characteristic map results that decreases monotonically in d
as well as in vr.

Additional dimensions of the characteristic map not shown in
Figure 2 relate to own vehicle speed v as well as to driver-
20   selected target time gap τ = d/vr with which a preceding
vehicle is to be followed. Every combination of values of
quantities V and τ yields an additional two-dimensional
characteristic map analogous to Figure 2 that may differ from
the characteristic map according to Figure 2, for example in
25   the selection of critical distance d0 and in the selection of
time interval T.

In Figure 2, two objects 44, 46 are drawn in as examples that
are represented by a corresponding value pair (vr, d). Both
30   objects 44, 46 are to be located in the own lane. Object 44 is
the directly preceding vehicle while object 46 is the vehicle
in front of the preceding vehicle and therefore is at a
greater distance d. While the directly preceding vehicle,
i.e., object 44, would normally be selected as the target

'object, the method described here for object selection results
in object 46, i.e., the vehicle in front of the directly
preceding vehicle, being selected as the target object in the
situation shown in Figure 2 because evaluation quantity g is
5   greater for this object 46. In practice, this would correspond
with the situation that the vehicle in front of the directly
preceding vehicle (object 46) performed an abrupt braking
operation so that its relative speed is very high according to
the amount. Directly preceding vehicle (object 44) has not yet
10   reacted to this braking operation and therefore still has a
relative speed of approximately 0. As a result of the method
described here, the selection of object 46 as the target
object would predictively take the braking operation of this
vehicle into account and would reduce the own vehicle speed
15   prior to the directly preceding vehicle reacting to the
braking operation. This system performance not only
contributes in practice to an increase in driving safety but
also to a significantly increase the continuity in traffic
flow in the case of high traffic density.
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In Figure 2, characteristic map 40 is divided into quadratic
or rectangular cells 48. Each of these cells 48 represents a
memory cell of the digital characteristic map memory. Cells 48
are different sizes in different regions of characteristic map
25   40, and they are smallest where evaluation quantity g changes
most radically, i.e., where isolines 42 are closest together.
The variable size of cells 48 results in sufficiently high
resolution of the characteristic map as well as a significant
decrease in the memory space requirement, in particular for
30   high-dimensional characteristic maps.